Waste Minimization Technologies for D&D of Radioactively-Contaminated Facilities

Steven J. Bossart
304-285-4643
steven.bossart@fetc.doe.gov

John R. Duda
304-285-4217
john.duda@fetc.doe.gov

U.S. Department of Energy
Federal Energy Technology Center
Deactivation and Decommissioning Focus Area
Morgantown, West Virginia

Summary. This paper describes the attributes of several innovative and improved decontamination and decommissioning (D&D) technologies that generate less waste compared to the competing baseline technologies. The innovative/improved D&D technologies include: Personal Ice Cooling System, VecLoader HEPA-VAC System, Soft-Sided Waste Containers, Concrete Dust Suppression System, Liquid Nitrogen-Cooled Wire Concrete Cutting, RESRAD-Build, Concrete Shaver, Lead TechXtract Chemical Decontamination, Stripping Coatings for Decontamination, and Long-Range Alpha Detector.

Keywords. Decontamination, decommissioning, waste minimization

Introduction. As a result of the end of the cold war, the U.S. Department of Energy (DOE) has over 5,000 surplus facilities which no longer serve the mission of producing nuclear weapons. DOE plans to decommission these aging facilities to reduce its cost to monitor and maintain the facilities; to decrease the potential to release radioactive and hazardous materials to workers, the public, and the environment; and to reduce the risk of industrial safety accidents due to continued deterioration of the buildings. A significant volume of low-level radioactive waste (LLW) will be generated during decontamination and decommissioning (D&D) of DOE's surplus facilities. This LLW consists of primary waste which includes the building structures and the contents of the buildings, and secondary waste which is the portion of the waste that is not part of the facility undergoing decommissioning . Primary waste includes asbestos, transite, concrete and metal structures, tanks, piping, vessels, pumps, and other equipment and construction materials. Secondary waste includes personal protective equipment (e.g., clothing, gloves, booties), decontamination media (e.g., water, chemicals, metal grit), tools (e.g., saw blades), particulate filters, ion exchange media, wiping rags, temporary enclosures, paper towels, and hoses. Many of the baseline technologies used to D&D DOE's facilities generate large quantities of secondary waste, which contributes significantly to the total volume of LLW which must be disposed in regulated LLW landfills.

To reduce the generation of waste destined for disposal in LLW landfills, the DOE's Deactivation and Decommissioning Focus Area (DDFA) has been conducting demonstrations of innovative and improved D&D technologies that minimize the generation of primary and secondary waste compared to competing baseline technologies. These technologies reduce the quantity of LLW by recycling materials generated during D&D or by reducing the generation of secondary waste.

The remainder of this paper discusses the attributes of several innovative and improved D&D technologies that generate less waste compared to the competing baseline technologies. The innovative/improved D&D technologies include: Personal Ice Cooling System, VecLoader HEPA-VAC System, Soft-Sided Waste Containers, Concrete Dust Suppression System, Liquid Nitrogen-Cooled Wire Concrete Cutting, RESRAD-Build, Concrete Shaver, Lead TechXtract Chemical Decontamination, Stripping Coatings for Decontamination, and Long-Range Alpha Detector.

These technologies span a wide range of D&D applications including equipment and concrete floor decontamination, facility characterization, facility demolition, worker protection, waste handling, and asbestos abatement.

Each of these innovative/improved D&D technologies was demonstrated in one of seven Large-Scale Demonstration and Deployment Projects (LSDDP) sponsored by the DDFA. In LSDDPs, innovative/improved D&D technologies are demonstrated alongside competing baseline technologies in ongoing deactivation and decommissioning projects at DOE sites. Performance data is collected during demonstration of both innovative/improved and baseline D&D technologies. Performance data include: cost, production rate, radiation exposure, waste generation, labor requirements, personal protective equipment requirements, equipment maintenance, worker safety, and ease of use. The LSDDP approach provides realistic and credible performance data because the technology demonstrations are conducted at commercial-scale within ongoing deactivation and decommissioning projects. In addition, the duration of the demonstrations is dictated by the end-users of the D&D technologies. This ensures that the demonstrations will provide end-users with conclusive data, thus enabling them to make informed technology decisions. This paper will focus on analysis of waste generation data collected during demonstration of several innovative/improved and baseline D&D technologies.

Personal Ice Cooling System (1,2). Delta Temax is marketing a Personal Ice Cooling System (PICS) which reduces heat stress to D&D workers and increases stay time. The PICS is a self-contained, cooling system that uses frozen water bottles to chill water which is circulated through tubing incorporated into a lightweight, full-body garment with detachable hood, shirt, and pants. The insulated ice bottle and pump are contained in an impermeable backpack attached to a harness. The assembly is worn on the worker's back or hip. The worker controls the degree of cooling using a two-speed control unit that regulates the flow of chilled water through the cooling garment. The two-liter ice bottle, circulation pump, and suit weigh about 12 pounds. The pump is powered by three D-cell batteries which provides up to eight hours of operation. The ice bottle on PICS can be easily changed inside contaminated areas without risk to the worker, which increases stay-times almost indefinitely. The bottles can be kept frozen in an ordinary household freezer and the cooling garments can be laundered in household washers and dryers.

During its demonstration in the FEMP Plant 1 LSDDP, workers wore the PICS while scraping paint in Building 68 at Fernald. The temperature inside the building was about 105 degrees F. The average stay time for workers wearing two layers of Level C protective clothing with respirators under these conditions was about 23 minutes. Stay times for workers wearing the PICS was about 92 minutes. For each ten-hour shift at Fernald, workers wearing PICS with Level C clothing performed 5.4 hours of productive work in the field compared to only 2.3 hours for workers wearing Level C protective clothing.

The PICS reduces the disposal of Level C protective clothing by increasing the productive hours that a worker spends in the field each shift and decreasing the hours for dressing, undressing, and resting to alleviate heat stress. For example, a D&D task which requires 1,000 hours of field work will need about 1,850 hours with a worker wearing PICS with Level C clothing. The 1,850 hours consists of 1,000 hours of productive field work and 850 hours of unproductive time spent dressing, undressing, and resting. This equates to 185 days of ten-hour shifts and disposal of 370 sets of Level C clothing assuming two changes of disposable Level C clothing per day. For comparison, D&D work which requires 1,000 hours of field work will require about 4,350 hours with a worker wearing Level C clothing with no cooling. This equates to 435 days of ten-hour shifts and disposal of 870 sets of Level C clothing assuming two changes per day. Thus, disposal of 500 sets of Level C clothing will be saved during a D&D task requiring 1,000 hours of field work.

VecLoader HEPA-VAC System (3,4). Vector Technologies markets a VecLoader high-efficiency particulate air (HEPA) vacuum (VAC) system to remove, vacuum, transport, and bag asbestos and other types of loose insulation. The VecLoader HEPA-VAC system is a trailer-mounted system that includes a diesel engine-powered vacuum, wet cyclone separator, HEPA filter, and five-inch diameter vacuum hose. The five-inch diameter vacuum hose can transport insulation at distances up to 500 feet to the wet cyclone separator for wetting and bagging.

In the Fernald Plant 1 LSDDP, the VecLoader was demonstrated to remove mineral wool sandwiched between transite panels of the building. The baseline approach used to remove loose insulation at Fernald is to place workers on man lifts who then manually remove the insulation and stuff it into bags. The demonstration showed that VecLoader HEPA-VAC System could remove 716 square feet per day (sq. ft./day) of 4-inch thick mineral wool insulation compared to only 197 sq. ft./day for manual removal of insulation with a three-person crew. One significant advantage of the VecLoader HEPA-VAC System is that it compacts the insulation nearly 60 percent compared to only 7 percent compaction achieved by manual removal and bagging. The additional compaction achieved by the VecLoader HEPA-VAC System results in fewer bags and a smaller volume of asbestos and other insulation for disposal. For example, the VecLoader HEPA-VAC System would compact 100 cubic feet of loose insulation into 40 cubic feet of waste, while manual removal and bagging would compact the loose insulation to only 93 cubic feet.

Soft-Sided Waste Containers (5). Many DOE sites use metal or wood containers to dispose of LLW generated by D&D projects. A typical container has a volume capacity of about 100 cubic feet and a weight capacity of 8,000 to 10,000 pounds.

Transport Plastics has developed a soft-sided waste container which is made from a 25-mil woven outer polypropylene fabric shell with a 2-mil water resistant coating and a 45-mil double layer polypropylene inner liner. The outer shell is equipped with 18 straps for lifting and securing the container. Each container is 7x8x5 foot, has a capacity of about 260 cubic feet and holds up to 24,000 pounds. The containers meet the U.S. Department of Transportation requirements for transport of materials with low specific activity and surface contaminated items.

The soft-sided waste container was demonstrated in the Idaho National Engineering and Environmental Laboratory LSDDP for disposal of debris generated by D&D projects including reinforced concrete, cinder block, metal, pipe, and soil. Use of the soft-sided waste container results in less waste because one soft-sided container can contain about the same volume and weight capacity as three metal boxes. The volume of the soft-sided waste container itself is about 19 cubic feet compared to about 40 cubic feet for the volume of three 12-gauge, 4x4x6 foot metal boxes. In addition, the soft-sided waste container reduces void space within the container and disposal cell because it conforms to the shape of the waste within it when placed in a disposal cell. In addition to reducing waste volume, the soft-sided waste container saves about $1,800 by replacing about three metal boxes at a cost of about $720 per box.

Concrete Dust Suppression System (6). Dust generated during facility demolition must be managed to protect worker health and control the spread of contaminants. In the Hanford C-Reactor LSDDP, an automated water spray system was demonstrated for control of concrete dust generated by a demolition ram fitted onto a Caterpillar excavator. The automated water spray system is mounted on the excavator and consists of a 540-gallon water tank, eight spray nozzles, and controls. The spray nozzles are located slightly behind the ram and directed at the dust source. The baseline approach used at Hanford to control dust generated during concrete demolition work is spraying water with manned fire hoses.

Because water from the automated water spray system is directed at the source of the dust, much less water is needed to control concrete dust compared to the baseline approach using workers with fire hoses. For demolition of a high wall of concrete, the automated water spray system used 1.7 gallons of water per cubic foot of concrete compared to 14 gallons of water per cubic foot of concrete for workers using fire hoses to suppress dust. For demolition of a concrete floor slab, the automated water spray system used 0.12 gallons of water per cubic foot of concrete compared to one gallon of water per cubic foot for workers using fire hoses. Thus, the automated water spray system generated eight times less wastewater to achieve the same level of dust suppression as workers using fire hoses. To demolish a high-wall room with about 14,600 cubic feet of concrete, the automated water spray system would save about $105,000 for water consumption and treatment compared to the baseline approach of using manned fire hoses to suppress dust.

Liquid Nitrogen Cooled Diamond Wire Cutting (7). Diamond wire is used commercially to cut through thick concrete structures. Typically, water is used to cool the diamond wire during cutting of contaminated concrete structures. This water can be collected and recycled to reduce the volume of water consumed and wastewater requiring treatment, but water recycle requires additional equipment such as pumps, filters, and containers. In the Hanford C-Reactor LSDDP, an alternative cooling medium, liquid nitrogen, was evaluated for cooling the diamond wire during cutting of a three-foot thick concrete wall at C-Reactor. One advantage of using liquid nitrogen for cooling is that the liquid nitrogen vaporizes quickly and does not generate contaminated water or other liquids that require further treatment. During the demonstration, the liquid nitrogen-cooled diamond wire generated no secondary wastewater, while the water-cooled diamond wire generated three gallons per square foot of face cut. Face cut is calculated by multiplying the length of the cut by the thickness (i.e., depth) of the cut. Water was not recycled in the diamond wire cutting tests in the C-Reactor LSDDP. Thus, use of liquid nitrogen to cool the diamond wire generates no liquid waste, while water cooling without recycle generates about three gallons of wastewater per square foot of cut. With water recycle, there will typically be 100-150 gallons of wastewater at the conclusion of cutting operations that requires treatment.

<u>RESRAD-Build (8)</u>. Currently, buildings and structures that have slight radioactive contamination are demolished and the debris is considered to be solid LLW, which requires disposal in a LLW burial facility. This method is costly, labor intensive, and lengthens the project schedule. One alternative is to employ the RESRAD-Build model and possibly leave the structures in place.

The RESRAD-Build model is an exposure pathway and analysis code used to determine whether radiologically-contaminated buildings and structures can be free released for a specific land use (e.g., residential or industrial). Argonne National Laboratory (ANL) developed the model to provide estimates of dose to a hypothetical receptor from the structure. When using the RESRAD-Build code, specific project assumptions must be developed with the appropriate regulatory agencies, especially the cleanup criteria and the exposure scenario to be used. The C- Reactor LSDDP demonstration of RESRAD-Build modeled the hypothetical future use of below-grade portions of the reactor building complex. A residential exposure scenario with a cleanup criteria of 15 mrem/yr above background was used to coordinate decommissioning with adjacent ongoing remedial actions.

Model results were applied to below-grade pipe tunnels at the C-Reactor building. Instead of demolishing and removing concrete structures that lay outside of the safe store enclosure as originally planned, surfaces were surveyed and sampled, and the floors and most of the walls were left in place. The tunnel ceilings and the upper one meter of the tunnel walls were demolished. Approximately one-half of the concrete debris was removed while the other half was allowed to fall to the floor of the tunnels. The remaining tunnel walls and floors remained intact. Steel piping and grating were surveyed and remained on-site. Implementation of RESRAD-Build at C-Reactor avoided a schedule delay of six weeks and reduced costs by 50%. Nearly $150,000 was saved, and over 350 cubic yards of concrete debris did not have to be removed and subsequently disposed in a LLW disposal cell.

<u>Concrete Shaver (9)</u>. Many DOE facilities undergoing D&D are chemically and/or radiologically contaminated. These facilities must be dismantled and the demolition waste sized into manageable pieces for handling and disposal. Concrete floors and expansive outdoor pads comprise a considerable portion of the debris. To facilitate this work, DOE requires a tool capable of removing the surface of radiologically-contaminated concrete surfaces to significantly reduce the volume of LLW. Marcrist Industries Limited's concrete shaver provides an attractive alternative to traditional methods of decontaminating floors, which is typically accomplished using pneumatic scabbling tools. At the C –Reactor LSDDP, the shaver demonstration was performed in an area formerly used as a sample room, with the goal of decontaminating the floors to free release levels in preparation for demolition.

The concrete shaver is a self-propelled, electric-powered, concrete diamond-shaving machine that can remove concrete surfaces with extremely accurate tolerances. This unit has a 10-inch wide shaving drum that is suitable for flat or slightly curved floors. The design for mounting the blades onto the drum results in low vibration levels. Infinitely variable shaving depths from 0.004 in to 0.5 in can be achieved. The depth of shaving is set by the use of a manual rotary wheel that is linked to a digital display. The system includes a vacuum extraction unit for dust-free operations. The travel rate is infinitely variable, giving a high production rate. The unit weighs 330 pounds and consumes 16 amps of 380-volt to 480-volt, 3-phase power, and has forward and reverse action.

At Hanford's C Reactor LSDDP, a productivity of five times the baseline scabbler was demonstrated which translated to an operational cost reduction of 50 percent. The volume of dust generated by the shaver was slightly less than the baseline, and the shaver leaves a smoother surface so final release surveying is more reliable. By deploying the highly efficient surface removal technology, minimal LLW is generated, and concrete floors/slabs can potentially be left in place or dispositioned as sanitary waste.

Lead TechXtract Chemical Decontamination (10). As part of the C-Reactor LSDDP, Active Environmental Technologies operated the TechXtract technology for the first production-scale demonstration of the technology on lead bricks. The demonstration indicated that the technology could reduce radioactivity to below surface free release requirements. Out of 80 bricks (1 ton) decontaminated, 78 bricks were releasable with activity levels that were equal to background levels or were non-detectable.

The TechXtract technology is a sequential chemical extraction process for the removal of radionuclides, PCBs, and other hazardous organic and inorganic substances from materials such as lead, concrete, construction bricks, and steel. The chemicals are scrubbed into the contaminated surfaces with ultrasonics for a specified time, then rinsed and removed with vacuum. The system is housed in a trailer with an overhead rail and hoist to handle bricks in batches of four. The decontamination stations inside the trailer consist of three heated, ultrasonic baths, two rinse stations with vacuum drying, and a final vacuum drying station. Waste contaminated liquids are removed using two vacuum systems with HEPA filters on the exhaust side. Wastes are captured in the vacuum drum body and later transferred to a disposal drum. Optionally, stabilization agents added to the liquids in the drum form a solid waste.

At Hanford, the baseline approach is to encapsulate contaminated lead bricks and bury them in a landfill as a mixed waste. Because of relatively low landfill costs at Hanford's Environmental Restoration Disposal Facility, the TechXtract process was not cost-competitive. However, the technology remains a viable decontamination option , which will allow the lead materials to be recycled as a valuable resource, instead of adding to disposal costs and the volume of wastes.

ALARA 1146 Strippable Coating (11). Often, residual contamination does not adhere to a surface, which can lead to an airborne activity problem. Using liquid decontamination agents to decontaminate surfaces is one option to deal with this problem, but in many instances, there is no guaranteed method to process the resulting liquid waste. For example, at Savannah River Site's (SRS) 321-M facility any liquid wastes generated would have to be collected and transported to another location for processing. Therefore, it is important to eliminate or minimize liquid wastes from this facility. Consequently, there is a need for a technology to remove surface contamination without producing liquid secondary waste.

ALARA 1146 is a water-borne vinyl strippable coating that is free of solvents and toxic materials. It is used to mechanically bind with radionuclides and remove them from substrates. The coating is manufactured by Carboline of St. Louis, Missouri. Williams Power Corporation is the exclusive vendor of the product and provided the spray application equipment and operational direction at the 321-M LSDDP. The main characteristics of this coating include rapid application and removal, reduced waste volumes, immobilization of surface contaminants, and reduction of surface contamination. This strippable coating has low odor and does not contain chlorides. Although the ALARA 1146 was demonstrated at SRS primarily on large flat surfaces, the product has also been proved effective in decontaminating components such as glove boxes, hand tools, casks, reactor headstands, reactor coolant pumps, reactor vessel studs, and underwater lights.

At the 321-M deactivation project, only six gallons of liquid waste were generated during the demonstration in which the coating was applied to over 2300 sq. ft. The secondary liquid waste was used to clean the spray equipment after its use. A cost evaluation is underway, but early indications suggest that ALARA 1146 is a superior alternative, and SRS has already deployed the strippable coating.

Long Range Alpha Detection for Component Monitoring (12). With the commencement of decommissioning activities, many items (e.g., pipe, tools, fluorescent light bulbs, small equipment) in contaminated areas must be appropriately dispositioned. These items may not become contaminated with radioactive materials during their normal use, but eventually become LLW unless they are proven to be free of contamination. For unrestricted release from a contamination area, these items must undergo radiological surveys to prove that radioactive contamination is not present on any surface. For items in areas with alpha contamination, this becomes difficult because of the very short range and poor penetration of alpha radiation. Contamination on inaccessible surfaces, such as the internal surfaces of small diameter pipe, cannot easily be measured, and therefore cannot be released for recycle or sanitary landfill disposal.

BNFL Instruments Inc.'s IonSens™ Cut Pipe Monitor measures alpha-emitting contamination on surfaces of materials including areas that are inaccessible to hand probe and smear surveys, but accessible to the flow of ambient air. While the costs of surveying items using the baseline technology varies with item complexity and surface area, measurement time of the IonSens™ system is the same for all items regardless of surface area or complexity. Therefore, the IonSens™ system provides cost savings when monitoring large or complex items and multiple items during single measurement cycles.

The technology was demonstrated at the SRS for clearance surveys during deactivation of the 321-M Fuel Fabrication Facility. When multiple items are monitored in a single measurement cycle, the cost of surveying was $1.70 per item compared to $3.30 per item using hand probes and smears. The measurement chamber volume is about one cubic foot for a single cycle, hence the single cycle cost of $8.50 is more than an order of magnitude less than SRS' disposal cost of $106 per cubic foot. Consequently, in situations involving suspect contaminated components, the IonSens™ system would be beneficial in reducing waste and saving money.

Conclusion. DOE's DDFA has been successful in identifying and demonstrating innovative/improved D&D technologies that minimize the generation of primary and secondary waste compared to competing baseline technologies. The DDFA intends to continue demonstrating and deploying waste minimization D&D technologies through its portfolio of LSDDPs. The subsequent deployment of these technologies in deactivation and decommissioning projects throughout the DOE weapons complex will reduce the amount of LLW that must be disposed in DOE and commercial LLW landfills. The reduction of waste generated from DOE's D&D projects will be increasingly important in the future as LLW landfills reach capacity and new LLW landfills become more difficult and costly to site and construct.

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<u>Biography</u>.

Since 1995, Steven J. Bossart and John R. Duda have been Senior Federal Project Managers in the DOE's Deactivation and Decommissioning Focus Area (DDFA) located in Morgantown, West Virginia. Their mission is to manage the development and demonstration of improved D&D technologies, and facilitate their deployment in DOE's decommissioning projects. Their responsibilities include management of Large-Scale Demonstration and Deployment Projects at Argonne National Laboratory, Hanford Reservation, Savannah River Site, Idaho National Engineering and Environmental Laboratory, and Los Alamos National Laboratory.